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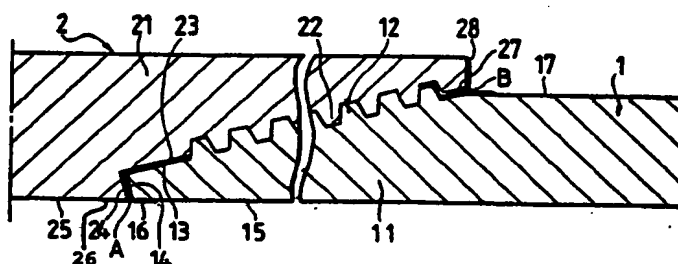
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(54) **Oil-well tubing joints with anti-corrosive coating.**

(57) A threaded joint having high crevice-corrosion resistance for high-alloy oil-well tubing containing not less than 7.5% by weight of Cr has those parts, including the sealing surface, of the joint that are directly exposed to a corroding environment covered with a coating (16,26) of non-metallic substance 1 to 100 μ m in thickness. The coating consists of a single layer or multiple layers of oxide, nitride or carbide ceramics.

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FIG. 1



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Joints for High-Alloy Oil-Well Tubing with Excellent Resistance to Crevice Corrosion

This invention relates to joints for oil-well tubing for use in the production of oil and natural gas, and more particularly to joints for high-alloy oil-well tubing that exhibit high corrosion resistance, more particularly high crevice-corrosion resistance, in environments in which H_2S , CO_2 and Cl^- are present.

With the progressive decrease in oil and natural gas resources, oil and gas production has come to be carried out in severer environments containing H_2S , CO_2 and chlorides or involving high temperatures. Conventional carbon- and low-alloy-steel oil-well tubing cannot be used in such environments because the corrosion rate is as heavy as 10 mm per year or more. Corrosion inhibitors extensively used with carbon- and low-alloy-steel oil-well tubing are difficult to be used in offshore wells because on costs and limited space for operation. Under such circumstances, the use of high-alloy oil-well tubing, made of alloys containing higher percentages of Cr, Ni, Mo and other alloying elements, has recently been on the increase.

For the production of oil and gas containing CO_2 but not H_2S , for example, 13% Cr steel and 9% Cr-1% Mo steel are widely used. For the production of oil and gas containing both CO_2 and minute amounts of H_2S , duplex stainless steels containing 22 to 25% of Cr are used. It is also known that Ni-Cr-Mo-Fe alloys containing, for example, more than 25% Ni, more than 20% Cr and more than 3% Mo exhibit high corrosion resistance in environments containing much H_2S .

Japanese Provisional Patent Publication Nos. 207142 of 1982 and 203740 of 1982 disclose alloys for use in severe environments containing large amount of H_2S . To those alloys, corrosion resistance is imparted by limiting the contents of such alloying elements as Ni, Cr, Mo and W. Rare earth elements, Y, Mg and Ca are added to enhance their hot workability.

In the alloy disclosed in Japanese Provisional Patent Publication No. 1044 of 1983, the contents of Cr, Mo, W, Ni and Mn are controlled to such limits as will impart high enough stress corrosion resistance in environments containing H_2S . While Cu and Co are added to increase corrosion resistance, rare earth elements, Y, Mg and Ca are added for the improvement of hot workability.

Oil and gas well environments containing H_2S , CO_2 and Cl^- are heavily corrosive. High-alloy oil-well tubing of the above-described conventional types used in such environments are designed to withstand general corrosion and stress-corrosion cracking. But no consideration has been given to another form of corrosion known as crevice corrosion that occurs within a crevice.

Pieces of oil-well tubing are jointed together with threaded joints. Each joint has a crevice at each end thereof surrounded by a high-alloy, with one end of the crevice opening toward a corrosive environment. The inventors studied the possibility of the occurrence of crevice corrosion in such threaded joints. From the studies, it was found that crevice corrosion can occur even on high-alloy steel as the service environment becomes severer. Indeed, occurrence of crevice corrosion on high-alloy steel is well-known, as was reported by Kudo et al, in "Tetsu to Hagane" vol. 73, No. 5, S, p.625 and vol. 73, No. 13, S, p.1387. Crevice corrosion in threaded joints can not only lead to stress-corrosion cracking but also damage the leak tightness of the joint, achievement of which is one of the important functions of the joint, by attacking the sealing surface thereof.

The inventors thoroughly analyzed the mechanism of crevice corrosion in environment containing H_2S , CO_2 and Cl^- ions. The analytical study revealed that crevice corrosion in such environment results from the reaction between concentrated metal ions (especially chromium ions) dissolved from the high-alloy and concentrated Cl^- ions from the environment, which drastically lowers the pH within the crevice to such an extent that the high-alloy can no longer maintain its corrosion resistance. Though initially remaining passive, high-alloy dissolves little by little in such environment, producing a concentration of metal ions within the crevice over a long time.

According to the studies of the inventors, it is extremely difficult to prevent such crevice corrosion in threaded joints by content adjustment of alloying metals. Even if possible, such adjustment would be prohibitively costly because crevice corrosion cannot be prevented unless corrosion resistance is enhanced beyond the limit adequate for the corrosive service environment in which the joint is to be used.

The object of this invention is to provide a threaded joint for high-alloy oil-well tubing in which no crevice corrosion occurs even in high-temperature and high-pressure environments containing H_2S , CO_2 and Cl^- by means of a non-metallic coating provided in the critical areas of the joint.

As mentioned previously, crevice corrosion occurs when dissolved and concentrated metal ions and concentrated Cl^- ions from the environment react to drastically lower the pH within a crevice to such an extent that high alloy can no longer remain corrosion resistant. After making studies on the inhibition of such crevice corrosion with such diverse approaches as alloying-element-content ad-

justment and environment control, the inventors found that crevice corrosion can be prevented by inhibiting the dissolution of metal ions through a coating of non-metallic substance around a crevice.

This invention is based on the above finding. Essentially, the invention relates to a threaded joint having high crevice-corrosion resistance for oil-well tubing of high-alloy containing not less than 7.5% by weight of Cr, in which those parts, including the sealing surface, of the joint that are directly exposed to a corrosive environment are covered with a coating of non-metallic substance 1 to 100 μm in thickness.

Non-metallic substances suited for the protective coating are such oxide ceramics as TiO_2 , Al_2O_3 , ZrO_2 and Cr_2O_3 , such nitride ceramics as TiN , AlN , ZrN and BN , and such carbide ceramics as TiC and ZrC . These non-metallic substances effectively prevent crevice corrosion in aqueous solutions containing H_2S , CO_2 and Cl^- . The same oxide ceramics (e.g., TiO_2 and TiO_2) or different oxide ceramics (e.g., TiO_2 and Al_2O_3) may be coated in two or more layers. Whether applied in a single layer or in multiple layers, the coating may be made up of a mixture of different types of ceramics (e.g., ZrO_2 and Cr_2O_3). Even if different types of ceramics are mixed together, their effect in the prevention of crevice corrosion remains unchanged. The same applies to nitride and carbide ceramics, too.

The Cr content in the high-alloy oil-well tubing is limited to not lower than 7.5% because corrosion resistance sufficiently high to withstand a corrosive environment cannot be obtained under 7.5%, with resulting failure in forming a stable passive coating which, in turn, leads to general corrosion. Where general corrosion has occurred, no crevice corrosion occurs. The upper limit of Cr content is not specified. But alloy steel containing an excessive amount of (e.g., in excess of 32%) Cr is practically and commercially difficult to make. Other alloying elements than Cr are chosen depending on the severity of service environment. Ni, Mo, W, Cu, Co and Fe are among those which are added as needed. This invention covers all alloying steels containing not less than 7.5% of Cr, regardless of the kind and content of other alloying elements.

Coatings thinner than 1 μm cannot inhibit the dissolution of metal ions to such an extent as to permit adequate prevention of crevice corrosion. On the other hand, the preventing effect of the coating for crevice corrosion will no longer increase even if its thickness is made greater than 100 μm . That is not all. Such excessively heavy coatings would impair the dimensional accuracy of threads and cause seizure during make-up. As such, the thickness of a coating must be limited between 1 and 100 μm . A coating within the above thickness

range may be formed either in single application or in multiple applications.

This invention provides high corrosion resistance to high-alloy oil-well tubing including threaded joints. The invention is described in connection with the drawings in which

Fig. 1 is a partial longitudinal cross section of a threaded joint for high-alloy oil-well tubing covered with a coating of non-metallic substance;

Fig. 2 is an enlarged view showing the inner part of the same threaded joint; and

Fig. 3 is an enlarged view showing the outer part of the same threaded joint.

This invention is intended for oil-well tubing for highly corrosive oil and gas wells that are connected together by joints assuring particularly high leak tightness known as premium joints. Various types of highly leak-tight joints have been proposed and used. A threaded joint of the type illustrated in Fig. 1 is an example.

As shown in Fig. 1, a threaded joint is made up of a pin member 11 provided at the tip of an oil-well tube and a box member 21 provided at each end (only one end is shown in the figure) of a coupling (a short-length connecting tube) 2. A tapered external thread 12 is provided on the pin member 11. The pin member 11 has a tapered annular tip whose outside surface serves as a sealing surface 13. The box member 21 has a tapered internal thread 22 matched to said external thread 12. The innermost inside surface of the box member 21 serves as a sealing surface 23 mating with the sealing surface 13 of the pin member 11. The surface next to the sealing surface 23 of the box member 21 is an annular inner end face 24 perpendicular to the sealing surface 23. An end face 14 of the pin member 11 faces the inner end surface 24 of the box member 21. One coupling 2 joins together two oil-well tubes 1, with the pin member 11 at the tip of each tube 1 being screwed into the box member 21 at each end of the coupling 2. The sealing surface 13 of the pin member 11 and the sealing surface 23 of the box member 21 are brought into contact to provide the required leak tightness.

As mentioned previously, the high-alloy oil-well tubing to be connected together contain not less than 7.5% of Cr. One or more of such alloying elements as Ni, Mo, W, Cu, Co, Nb, Ca, Si, Mn and Fe may also be contained.

Some examples containing several alloying elements are given below. Ni and Mo are added to provide corrosion resistance. (Ni, in particular, provides sour-corrosion resistance.) Si and Mn are added for the purpose of deoxidation and securing adequate strength. Cu and N, respectively, enhance sour-corrosion resistance and strength. Low-

er contents of P and S are conducive to the securing of corrosion resistance.

A first example of high-alloy steel oil-well tubing contains (the percentages shown are all by weight):

(a) Cr: 7.5 - 14.0%, C: 0.25% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., S: 0.02% max., Al: 0.15% max.;

at least either of the following (b) and (c)

(b) one or more of Ni: 4% max., Mo: 2.5% max., and Cu: 1% max.

(c) N: 0.12% max.; and

Fe and ordinarily associated impurities.

In the above example, Cr content is limited between 7.5 and 14.0% to enhance carbon-dioxide corrosion resistance. The C content at 0.25% or less permits securing adequate strength. Addition of Al results in stronger deoxidation.

A second example of high-alloy oil-well tubing contains, by weight:

(a) Cr: 18.5 - 28.0%, Ni: 4.5 - 9.5%, Mo: 2.5 - 5.5%, C: 0.12% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., and S: 0.02% max.;

at least either of the following (b) and (c)

(b) Cu: 1% max.

(c) N: 0.20% max.; and

Fe and ordinarily associated impurities.

In this example, the higher Cr content between 18.5 and 28.0% enhances sour-corrosion resistance. The lower C content at 0.12% provides adequate corrosion resistance. A third example of high-alloy oil-well tubing contains, by weight:

(a) Cr: 14.5 - 28.0%, Ni: 20 - 62%, Mo: 2.5 - 18%, C: 0.12% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., and S: 0.02% max.;

at least either of the following (b) and (c)

(b) one or more of Cu: 1% max, Ti: 1.5% max., Nb: 5% max., and Ca: 0.02% max.

(c) N: 0.3% max.; and

Fe and ordinarily associated impurities.

In this example, the higher Cr content between 18.5 and 28.0% enhances sour-corrosion resistance, while the lower C content at 0.12% max. provides adequate corrosion resistance. Nb and Ca are added to increase strength and hot workability, respectively.

In a threaded joint of the type described previously, a clearance A is left between the end face 14 of the pin member 11 and the inner end face 24 of the box member 21 and a clearance B between the base of the pin member 11 and the tip (opposite to the inner portion) of the box member 21. Crevice corrosion occurs in such clearances as mentioned above. According to this invention, therefore, the end portions including the sealing surfaces which are directly exposed to corrosive environment are covered with a coating of non-metallic substance 1 to 100 μ m in thickness. More

specifically, the sealing surface 13, the end face 14 and a part of the internal surface 15 around at the tip of the pin member 11 are covered with a coating 16 of non-metallic substance, as shown in an enlarged view in Fig. 2. Similarly, the sealing surface 23, the inner end face 24 and a part of the internal surface 25 around at the base of the box member 21 are covered with a coating 26 of non-metallic substance. Furthermore, the external surface 17 at the base of the pin member 11 and the internal surface 27 and the end surface 28 at the tip of the box member 21 are covered with a coating 29 of non-metallic substance, as shown in an enlarged view in Fig. 3. Consequently, the clearances A and B are enclosed with the coatings 16, 26, 19 and 29 of non-metallic substance.

For such coating, a non-metallic substance having sufficiently high corrosion resistance to withstand the corrosive service environment must be chosen. From a commercial viewpoint, no excessively costly substance cannot be used as the coating material. A suitable coating material may be chosen from among such oxides as TiO_2 , Al_2O_3 , ZrO_2 and Cr_2O_3 , such nitrides as TiN , AlN , ZrN and BN , and such carbides as TiC and ZrC mentioned before.

The coating of non-metallic substance may be applied by any method so long as the specified thickness can be obtained. For example, ion plating, sputtering, CVD (chemical vapor deposition), plasma CVD and spraying may be employed. The coating of non-metallic substance need not be perfect or free of such defects as crevices and pores. The coating having some such defects is practically acceptable so long as the dissolution of metal irons can be held below the desired limit. But, of course, it is desirable to reduce such defects to a minimum because larger crevices or too many defects can impair the crevice corrosion inhibiting effect.

Similar crevice corrosion inhibiting effect can be obtained even if several oxides, nitrides and carbides are mixed together. Therefore, either a single-substance coating or a multiple-substance coating may be chosen by taking into account such factors as coating speed and cost. A coating within the specified thickness range of 1 to 100 μ m may be formed either in a single layer or in multiple layers. Multi-layered coatings are more effective in inhibiting crevice corrosion because fewer defects in the coating are exposed to corrosive environment.

Some concrete examples of non-metallic coatings and their crevice corrosion resistance are given in the following.

Threaded joints were provided to the high-alloy oil-well tubes shown in Table 1. After applying the non-metallic coatings listed in Table 2 on critical

portions of the threaded joints, the tubes were subjected to corrosion test. The oil-well tubes had an outside diameter of 88.9 mm and a wall thickness of 6.45 mm. The non-metallic coatings were applied by sputtering.

With specimens Nos. 1 and 7 according to this invention in Table 1 and 2, the areas from the sealing surfaces to the internal surfaces of the joint (at the tip of the pin member 11 and the base of the box member 21) were coated. With specimens Nos. 8 to 12 according to this invention, the areas from the sealing surfaces to the internal surfaces of the joint (at the tip of the pin member 11 and the base of the box member 21) and the areas at the outer end of the joint (at the base of the pin member 11 and the tip of the box member 21) were coated. With specimen No. 14 tested for comparison, the areas from the sealing surfaces to the internal surfaces of the joint were coated, but the coating did not satisfy the requirement of this invention in the asterisked (*) point. No non-metallic coating was given to specimens Nos. 13 and 15 to 17 for comparison.

After being placed in the corrosive environments shown in Table 2 for one month, the specimens were inspected for the occurrence of crevice corrosion in their joints. The corrosive environments in Table 2 were chosen depending on the corrosion resistance of the individual high-alloy oil-well tubes tested.

As is obvious from Table 2, no crevice corrosion occurred on specimens Nos. 1 to 12 whose joint clearances were coated according to this invention. By contrast, crevice corrosion occurred on specimens Nos. 13 and 15 to 17 because no protective coating was applied over the clearances and on specimen No. 14 because, though coating was applied, the coating thickness was insufficient.

This invention is by no means limited to the preferred embodiments described. The threaded joint shown in Fig. 1 has the sealing surfaces extending along the length of the tube. But this invention is also applicable to the threaded joints on such tubes whose sealing surfaces are perpendicular to or nearly perpendicular to the length thereof. The threaded joint of Fig. 1 is of the coupling type which comprises the pin member 11 on the tube 1 and the box member 21 on the shorter tube known as the coupling 2. This invention is also applicable to threaded joints of the integral type (in which connection is achieved by means of an external thread cut at one end of a tube and an internal thread cut at the other end, without using a coupling). With both types of threaded joints for high-alloy oil-well tubing, this invention provides excellent crevice corrosion resistance.

With the threaded joint shown in Fig. 1, the

sealing surfaces 13 and 23 and the internal surfaces 15 and 25 at the tip of the pin member 11 and the base of the box member 21, which are exposed to the corroding environment on the inner side of the joint, are covered with non-metallic coatings 16 and 26. Also, the areas from the external surface 17 at the base of the pin member 11 and the internal surface 27 at the tip of the box member 21 to the threads 12 and 22, which are exposed to the corroding environment on the outer side of the joint, are covered with non-metallic coatings 19 and 29. But, non-metallic coating may be given only to such portions as are exposed to corrosive environment on the inner side. The threads 12 and 22 need not always be coated, as well. Whether the non-metallic coating should be applied to only the portion exposed to the corrosive environment inside a tube or both the portions exposed to the corrosive environment on the inner and outer sides may be chosen depending on the severity of the individual corrosive environment and quality of high-alloy oil-well tubing. Usually, the inner side of oil-well tubing is exposed to a severer corrosive environment. Therefore the coating must be applied at least to the portions exposed to the corrosive environment on the inner side; namely, the sealing surface 13, end face 14 and internal surface 15 at the tip of the pin member 11 and the sealing surface 23, inner end face 24 and the internal surface 25 at the base of the box member 21. But it is preferable to apply the coating also to the portions exposed to the corroding environment on the outer side where there is a chance of a concentrated solution of salt (such as a 38% solution of CaCl_2 or a 44% solution of NaBr) used as a completion fluid of oil and gas wells (the solution surrounding the tubing) corroding the outer side of the thread. In view of the object of this invention, the non-metallic coating need not be applied to the internal and/or external surface of the oil-well tubing proper. But it may require a complex process to confine coating to the clearances, avoiding the internal and/or external surface of the tubing proper. Therefore, the coating area may include the internal and/or external surface near each end of the tubing proper. Threaded joints for high-alloy oil-well tubing in which coating is applied not only to the clearance areas but elsewhere are also, therefore, within the scope of this invention.

Table 1

No.	Main Constituents of High-Alloy Oil-Well Tubing										(Percent by Weight)		
	Cr	Ni	Mo	C	Si	Mn	P	S	Fe	Others			
Specimens According to This Invention	13.1	0.04		0.21	0.35	0.47	0.015	0.0011	Bal.				
	9.07		1.13		0.25	0.33	0.012	0.0027	Bal.				
	22.3	5.71	3.09	0.017	0.32	1.40	0.010	0.0005	Bal.	N 0.17			
	25.6	7.30	3.15	0.013	0.29	0.31	0.012	0.0012	Bal.	N 0.15			
	21.8	42.2	3.06	0.023	0.15	0.24	0.022	0.0007	Bal.	Cu 1.31, Ti 0.92			
	22.7	49.3	6.42	0.011	0.28	0.26	0.020	0.0025	Bal.	Cu 1.52			
	21.3	Bal.	9.22	0.019	0.36	0.57	0.026	0.0033	4.52	Nb 3.55			
	12.7	0.25		0.19	0.41	0.29	0.011	0.0028	Bal.				
	21.6	5.49	2.99	0.025	0.38	0.85	0.023	0.0009	Bal.	N 0.18			
	26.8	51.0	2.1	0.02	0.22	0.79	0.016	0.0015	Bal.	N 0.12, Nb 0.8			
	25.3	49.6	4.03	0.02	0.20	1.00	0.015	0.0004	Bal.	Ca 0.005			
	21.5	25.4	3.7	0.02	0.25	0.64	0.012	0.0003	Bal	Cu 1.5			
Specimens Tested for Comparison	13.0	0.18		0.22	0.30	0.49	0.022	0.004	Bal.				
	22.5	5.56	3.03	0.024	0.38	1.25	0.021	0.0017	Bal.	N 0.15			
	22.7	5.46	2.85	0.020	0.26	1.36	0.019	0.0025	Bal.	N 0.18			
	21.3	25.6	4.06	0.016	0.07	0.15	0.011	0.0007	Bal.	Ti 0.46			
	20.5	36.2	2.54	0.015	0.16	0.49	0.022	0.0008	Bal.				

Table 2

No.	Nonmetallic Coatings		Corrosion Test Conditions				
	Position of Coating	Coating Material and Thickness	Temperature (°C)	Partial Pressure of H ₂ S (atm)	Partial Pressure of CO ₂ (atm)	Concentration of NaCl (%)	Occurrence of Crevice Corrosion
Specimens Tested for Comparison	1	Al ₂ O ₃ 1.6 µm	100	0.001	40	5	o
	2	TiC 20 µm	110	0.001	10	5	o
	3	TiN 15 µm	200	0.1	20	10	o
	4	TiO ₂ 85 µm	200	0.1	20	10	o
	5	TiN 23 µm	200	1	10	20	o
	6	ZrN 10 µm	180	10	10	20	o
	7	TiN 10 µm+ZrN 10 µm	200	20	20	20	o
Specimens According to This Invention	8	Cr ₂ O ₃ +Al ₂ O ₃ 27 µm	120	0.001	40	5	o
	9	AlN 35 µm	150	0.2	40	10	o
	10	BN 18 µm	150	10	10	20	o
	11	ZrO ₂ 7 µm	150	20	20	20	o
	12	TiN+(AlN+ZrN) 5 µm	150	20	20	20	o
	13	-	150	0.002	40	5	Δ
	14	TiN 0.3 µm*	100	0.2	40	20	x
	15	-	120	0.05	40	20	x
	16	-	200	5	40	20	x
	17	-	100	1	40	20	x

o: No crevice corrosion, Δ: Light crevice corrosion, x: Heavy crevice corrosion

Claims

1. A joint for high-alloy oil-well tubing with high crevice corrosion resistance containing not less than 7.5% by weight of Cr having a pin member (11) and a box member (21) cut with matching threads (12, 22), both members (11, 21) having sealing surfaces (13, 23) adapted to be brought into contact with each other;

the sealing surfaces (13, 23) and other end portions of the pin and box members directly exposed to corrosive environment being covered with a coating (16, 26) of 1 to 100 μm in thickness which consists of at least one of oxide ceramics, nitride ceramics and carbide ceramics.

2. A joint for high-alloy oil-well tubing according to claim 1, in which said coating (16, 26) is provided to the sealing surface (13), end face (14) and internal surface (15) at the tip of the pin member (11) and the sealing surface (23), inner end face (24) and the internal surface (25) at the base of the box member (21).

3. A joint for high-alloy oil-well tubing according to claim 1, in which said coating is provided to the sealing surface (13), end face (14), internal surface (15) at the tip and external surface (17) at the base of the pin member (11) and the sealing surface (23), inner end face (24), the internal surface (25) at the base, internal surface (27) at the tip end face (28) of the box member (21).

4. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said oxide ceramics consists of TiO_2 , Al_2O_3 , ZrO_2 or Cr_2O_3 .

5. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said oxide ceramics consists of a mixture of at least two substances selected from the group of TiO_2 , Al_2O_3 , ZrO_2 and Cr_2O_3 .

6. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said coating is provided in multiple layers, each layer consisting of one of TiO_2 , Al_2O_3 , ZrO_2 , Cr_2O_3 and/or a mixture of at least two substances selected from the group of TiO_2 , Al_2O_3 , ZrO_2 and Cr_2O_3 .

7. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said nitride ceramics consists of TiN , AlN , ZrN or BN .

8. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said nitride ceramics consists of a mixture of at least two substances selected from the group of TiN , AlN , ZrN and BN .

9. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said coating is provided in multiple layers, each layer consisting of one of

TiN , AlN , ZrN , BN and/or a mixture of at least two substances selected from the group of TiN , AlN , ZrN and BN .

10. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said carbide ceramics consists of TiC or ZrC .

11. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said carbide ceramics consists of a mixture of TiC and ZrC .

12. A joint for high-alloy oil-well tubing according to claim 1, 2 or 3, in which said coating is provided in multiple layers, each layer consisting of one of TiC , ZrC and/or a mixture of TiC and ZrC .

13. A joint for high-alloy oil-well tubing according to claims 1 to 12, in which said high-alloy steel oil-well tubing contains, in percent by weight:

(a) Cr: 7.5 - 14.0%, C: 0.25% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., S: 0.02% max., and Al: 0.15% max.;

at least either of the following (b) and (c)

(b) one or more of Ni: 4% max., Mo: 2.5% max., and Cu: 1% max.

(c) N: 0.12% max.; and

Fe and ordinarily associated impurities.

14. A joint for high-alloy oil-well tubing according to claims 1 to 12, in which said high-alloy steel oil-well tubing contains, in percent by weight:

(a) Cr: 18.5 - 28.0%, Ni: 4.5 - 9.5%, Mo: 2.5 - 5.5%, C: 0.12% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., and S: 0.02% max.;

at least either of the following (b) and (c)

(b) Cu: 1% max.

(c) N: 0.20% max.; and

Fe and ordinarily associated impurities.

15. A joint for high-alloy oil-well tubing according to claims 1 to 12, in which said high-alloy steel oil-well tubing contains, in percent by weight:

(a) Cr: 14.5 - 28.0%, Ni: 20 - 62%, Mo: 2.5 - 18%, C: 0.12% max., Si: 1% max., Mn: 2.5% max., P: 0.004% max., and S: 0.02% max.;

at least either of the following (b) and (c)

(b) one or more of Cu: 1% max., Ti: 1.5% max., Nb: 5% max., and Ca: 0.02% max.

(c) N: 0.3% max.; and

Fe and ordinarily associated impurities.

FIG. 1

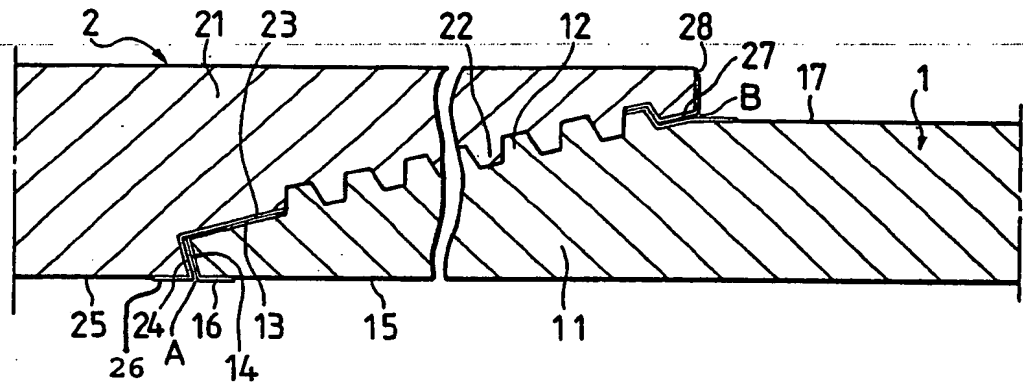


FIG. 2

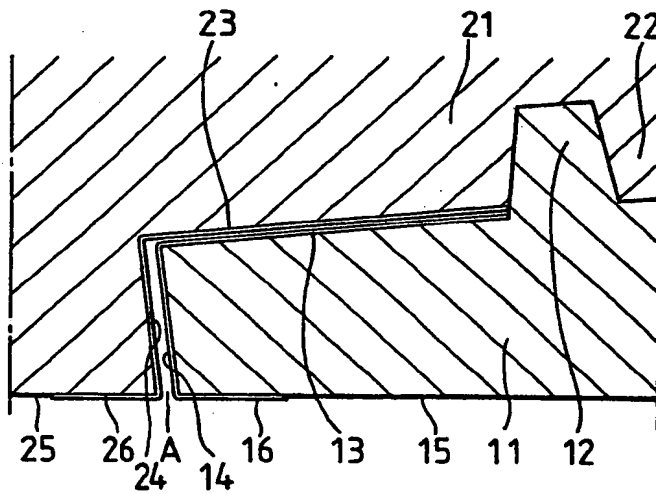
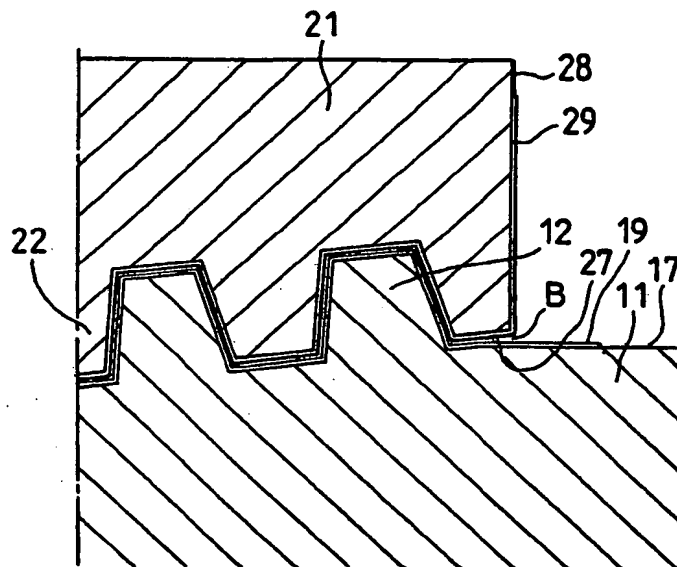


FIG. 3





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Application Number

EP 89 10 1808

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	GB-A-2 104 919 (SUMITOMO METAL INDUSTRIES LTD) * Abstract *	1-14	E 21 B 17/042 F 16 L 58/18
A	WO-A-8 503 249 (TELECO OIL FIELD SERVICES) * Abstract; claim 1 *	1-14	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			E 21 B F 16 L
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 21-04-1989	Examiner HEDEMANN, G.A.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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